Meat Science 96 (2014) 1227–1232

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Effects of blade tenderization, aging method and aging time on meat quality characteristics of *Longissimus lumborum* steaks from cull Holstein cows☆

Ersel Obuz [a,*], Levent Akkaya [b], Veli Gök [c], Michael E. Dikeman [d]

[a] College of Engineering, Bioengineering Department, Celal Bayar University, Muradiye-Manisa, Turkey
[b] College of Veterinary Medicine, Food Hygiene and Technology Department, Balıkesir University, Balıkesir, Turkey
[c] College of Engineering, Food Engineering Department, Afyon Kocatepe University, Afyonkarahisar, Turkey
[d] Department of Animal Sciences & Industry, Kansas State University, Manhattan, KS 66506, USA

ARTICLE INFO

Article history:
Received 20 March 2013
Received in revised form 15 November 2013
Accepted 19 November 2013

Keywords:
Cull Holstein cows
Aging
Blade tenderization
Warner–Bratzler Shear Force
Tenderness

ABSTRACT

The effects of blade tenderization (BT), two aging methods (dry (D) and wet (W)), and aging time (2 and 23 d) on tenderness, color, and sensory properties of *Longissimus lumborum* muscles from 12 cull Holstein cows were evaluated. Dry-aged loins had higher combined trim and aging losses than control (C) for both D- and W-aging, mostly because of excess trim losses. BT steaks had WBSF of 33.13 N while C steaks had WBSF of 41.46 N ($P = 0.09$). Aging decreased WBSF. Blade tenderized steaks had higher cook loss than C steaks. Aging, W-aging, and BT × W-aging improved myofibrillar (sensory) tenderness scores. Aging and/or BT improves sensory panel tenderness cull cow *Longissimus lumborum* steaks. Aging and blade tenderization combined can increase tenderness and value of *Longissimus* steaks from cull Holstein cows.

1. Introduction

Cows are generally culled from beef or dairy herds for various reasons, such as low productivity, poor health or condition, poor temperament, age, failure to reproduce, and (or) management decisions by the producer. In the USA, dairy cows accounted for 8.3% of all cattle harvested in 2010 (USDA, 2011). However, beef from mature cull cows have been reported to have inferior palatability characteristics as compared to young cattle (Dikeman & Tuma, 1971; Tuma, Henrickson, Odell, & Stephens, 1963). Thus, whole muscle cuts from cull cow beef have been utilized limitedly because of poor eating quality (tenderness, juiciness, flavor) and lack of consistency in tenderness (Stelzleni, Patten, Johnson, Calkins, & Gwartney, 2007; Xiong et al., 2007). Increased toughness in cull cow beef can be attributed to increased cross-links in collagen fibrils (connective tissue) as the animals mature (Shorthose & Harris, 1990).

Beef tenderness has been listed as one of the most important factors affecting consumer satisfaction (Dikeman, 1987; Savell et al., 1989). To this end, several postmortem tenderization techniques including aging (Dikeman, Obuz, Gök, Akkaya, & Stroda, 2013; Parrish, Boles, Rust, & Olson, 1991; Sitz, Calkins, Feuz, Umberger, & Eskridge, 2006), blade tenderization (George-Evins, Unruh, Waylan, & Marsden, 2004; Heller et al., 2007; Hopkins, 2004), injection with calcium and/or phosphate solutions (Baublits, Pohlman, Brown, & Johnson, 2005; Burke & Monahan, 2003), and enzyme or enzyme containing fruit based solution addition (Christensen et al., 2009; Pietrasik & Shand, 2011; Toohey, Kerr, van de Ven, & Hopkins, 2011) have been extensively used by the meat industry. Blade tenderization significantly improves the tenderness of less tender cuts of meat and is very effective in ensuring tenderness (Kolle, McKenna, & Savell, 2004; Pietrasik & Shand, 2004, 2005). About 85% of all meat purveyors have been reported to blade tenderize meat in the USA (George-Evins, 1999). Blade tenderization involves the penetration of the meat with closely spaced thin blades having sharpened edges (Pietrasik & Shand, 2004), which cut the muscle fibers into shorter segments and physically disrupts muscle fibers and muscle connective tissues (Parrish, 1977; Pietrasik & Shand, 2005).

Aging is widely used in the meat industry as it increases tenderness and flavor of meat (Sitz et al., 2006). The meat industry generally utilizes two types of aging; vacuum and dry aging. Dry-aged beef has a distinctive flavor, which differs significantly from "wet-aged" flavor of beef produced by vacuum packaging (Warren & Kastner, 1992). In vacuum aging, meat is stored at refrigerated temperatures in a sealed, oxygen-

☆ Contribution no. 13-263-J from the Kansas Agricultural Experiment Station.

* Corresponding author at: College of Engineering, Bioengineering Department, Celal Bayar University, 45140 Muradiye, Manisa, Turkey. Tel.: +90 236 2412144; fax: +90 236 2412143.
E-mail address: ersel.obuz@cbu.edu.tr (E. Obuz).

0309-1740/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.meatsci.2013.11.015

impermeable barrier package, whereas in dry aging, meat is unpackaged and exposed to air at controlled temperature and relative humidity (Parrish et al., 1991).

Cow meat is widely used in food service as ground beef or sausage ingredients because its inferior palatability and color instability in the form of steaks or roasts do not make it a viable choice for retail. In numerous countries, the major source of beef is from cull dairy cows. To our knowledge, no research has been published on different methods of aging and/or blade tenderization of major muscles from cull dairy cows. Therefore, it could be very valuable to improve the condition and quality of meat from cull dairy cow carcasses to meet demands of consumers for steak and roast items. Thus, the objectives of this study were to study the effects of aging method (dry or vacuum aging), and blade tenderization on aging and cooking losses; chemical composition; instrumental and visual color; and instrumental and sensory panel traits of beef steaks from Holstein cull cows.

2. Materials and methods

2.1. Raw material preparation

Subprimals (beef loin, strip loin, NAMP 174, 1997) from 12 cull Holstein cows were purchased from a large commercial processor. Carcass weights ranged from 325 to 375 kg; marbling ranged from Slight^{+} to modest^{+}; fat thickness measured on the 12th rib ranged from 3 to 6 mm; maturity ranged from C^{+} to D^{+}. At the Kansas State University meat laboratory, the *psoas major* muscle and all bones were removed leaving a boneless strip loin consisting primarily of the *Longissimus lumborum* muscle and associated subcutaneous fat. Treatments (blade tenderization or control) were randomly applied to loins (six loins per treatment). Strip loins were passed through a blade tenderizer (model T7001; Ross Industries Inc., Midland, VA) two times, with the external fat side down. Blades were 3 × 1 mm; 280 blades were transverse and 280 were longitudinal to the loins. Loins were divided transversely into two equal portions that were randomly assigned to one of the two aging treatments: (wet aging (W), or dry aging (D) with equal number of anterior and posterior halves in each treatment. Loin sections were either aged for 2 days or 23 days. The bags (8600-14EL, Cryovac Sealed Air Corporation, Duncan, SC) used for wet (W) aging had O_2 permeability of 3–6 ml of $O_2/m^2/24$ h at 4.4 °C, atmospheric pressure, and 0% relative humidity; water vapor permeability of 0.5–0.6 g/64.516 $cm^2/24$ h at 37.8 °C and 100% relative humidity. Loin sections destined for dry (D) aging were aged unpackaged with direct exposure to air in the cooler.

2.2. Aging conditions

Loin sections were aged for 2 or 23 d at 2.2 °C. Loins were placed on wire racks, with the subcutaneous fat surface down.

2.3. Steak preparation

Four 2.54 cm-thick steaks were removed from the anterior end of all loin half sections and randomly assigned to Warner–Bratzler shear force determination and sensory analysis. A sample was also taken from the anterior end of the LL for compositional analysis and pH. Steaks for sensory evaluation were frozen at −40 °C until just before evaluations by a trained sensory panel.

2.4. Weight, trim and combined losses

Each loin section was weighed on day 2 and day 23 of aging time. Weight (shrink) loss percentage was calculated as follows:

$$\text{Weight loss}\ (\%) = ((\text{weight before aging} - \text{weight after aging}))/((\text{weight before aging}))$$

After dry aging, loin sections were trimmed to remove dry and discolored portions. Any fat or muscle that was considered unattractive or unwholesome was removed. Wet aged loins were blotted by dry paper towels. The percentage trim loss was calculated as follows:

$$\text{Trim loss}\ (\%) = ((\text{weight loss due to trimming}))/((\text{untrimmed weight})) \times 100$$

Combined loss was also calculated using the following formula:

$$\text{Combined loss}\ (\%) = ((\text{weight before aging} - \text{trimmed weight}))/((\text{weight before aging})) \times 100$$

2.5. pH, moisture, fat

Samples of *Longissimus lumborum* tissue approximately 10 mm thick from the anterior end of each loin half section were frozen in liquid nitrogen and pulverized in a Waring blender (Dynamics Corp. of America, New Hartford, CT). Ten grams of pulverized sample was added to 100 mL of distilled water and mixed for 30 s, and pH values were obtained with an Accumet glass electrode attached to an Accumet 50 pH meter (Model 6.05, SFK Technology Inc., Peosta, IA). Moisture and fat content were determined using the CEM (CEM, Corporation; Mathews, NC) SMART (moisture) and SMART Trac (fat) systems.

2.6. Instrumental and visual color

Color measurements on the *Longissimus lumborum* steaks were taken before and after cooking with a colorimeter equipped with a 2.54 cm diameter orifice (Hunter MiniScan XE, model 45/0-L, Hunter Associates Laboratory Inc., Reston, VA, USA). Five measurements were collected on each steak after 20–25 minutes of bloom time. On the cooked steaks, L^* a^* b^* values were determined on the internal cut surfaces and internal visual color was evaluated to the nearest 0.5 unit on a 6-point scale: 1 = raw red centre, pink border, tan edge (medium rare); 2 = reddish-pink centre, pink border, tan edge; 3 = pinkish red centre, pink to light brown/tan to outer surface; 4 = slightly pink centre, light brown to tan edge (medium); 5 = tan/brown centre and edges, no evidence of pink; 6 = dry, brown throughout (well done; AMSA, 1991).

2.7. Shear force

Steaks were thawed at 4 °C for 24 hr and then cooked at 163 °C in a forced-air convection oven (DFG-102 CH3; G.S. Blodgett CO., Burlington, VT) to an internal core temperature of 71 °C. The center temperature profile of each steak was monitored using copper–constantan thermocouples (Omega Engineering, Stamford, CT) inserted into the approximate geometric center of each steak. Temperature was recorded every 1 min until the desired temperature was reached. The temperature profile for each steak was recorded by a Doric temperature recorder (VAS Engineering, San Francisco, CA), which was interfaced to a computer.

After cooking, steaks were cooled for 24 h at 2 °C following AMSA (1995) procedures and six round cores (1.27 cm diameter) per steak were removed parallel to the long axis of the muscle fibers (AMSA, 1995) using a mechanical coring device. Each core was sheared once using a Warner–Bratzler shear attachment (V-notch blade), which was connected to an Instron Universal Testing Machine (Model 4201, Instron Corp., Canton, MA). The compression load cell used was 50-kg and the crosshead speed was 250 mm/min.

Shear-force steaks were also used to determine cooking loss using the following formula:

$$\text{Cooking loss (\%)} = ((\text{raw weight-cooked weight}))/((\text{raw weight})) \times 100$$

2.8. Sensory analysis

Steaks for sensory were thawed at 4 °C for 24 hr and then cooked by the same procedure as for WBSF. Panelists ($n = 8$) were trained according to AMSA (1995) guidelines that involved triangle screening tests; 6 to 8 training sessions by a panel leader; then statistical evaluation of panelists that were presented six samples with distinct tenderness, flavor, and juiciness differences replicated on 4 different days. Trained panelists in the study had more than 100 hours of experience. All panel sessions were performed in an environmentally controlled (21 ± 1 °C, 55 ± 5% RH) booth-partitioned room with a mixture of adjustable red light (<107.64 lumens) and green light (<107.64 lumens). An orientation ("warm up") sample was evaluated and the scores given by the panel leader were discussed with the panelists before each session. One steak from each aging method × blade tenderization × aging time (8 steaks) combination was evaluated in a panel session. This required six sensory panel sessions. Each steak was cut into 1.27 × 1.27 × 2.54 cm pieces and randomly identified with three-digit-codes. Trained panelists evaluated palatability attributes on an eight-point scale for myofibrillar tenderness, juiciness, flavor, overall tenderness, and connective tissue amount (1 = extremely tough, dry, bland, tough, and abundant; 8 = extremely tender, juicy, intense, tender, and none) for each sample. Myofibrillar tenderness was evaluated after 4–6 chews, whereas connective tissue was evaluated as the residue left in the samples just before they would normally be swallowed. Unsalted crackers and deionized rinse water were given to panelists between individual samples and the panelists evaluated samples in a randomized order.

2.9. Statistical design and analysis

The overall treatment structure was a split–split-plot design with the incomplete assignment of the treatment combinations to the experimental units. The whole plot treatment was mechanical treatment (blade or control), the sub-plot treatment was aging method (dry aging and wet aging), and the sub–sub-plot treatment was aging time (2 or 23 days). Random effects included loin within mechanical treatment and aging method × loin within mechanical treatment. The treatment combinations were replicated six times. Data were analyzed using the PROC MIXED procedure of SAS (2009). The degree of freedom computation method was the Kenward–Roger (ddfm = kr) and it was included in the model statement. PROC MIXED NOBOUND option was used when one of the random effects estimate yielded 0 for variance components. Least squares means for all significant effects were calculated and means separated when significant ($P < 0.05$) using the PDIFF option.

3. Results and discussion

3.1. Weight, trim and combined losses

Treatment (blade tenderized or control; BT and C) and aging method interactions were significant ($P < 0.01$) for weight loss, but not for trim or combined loss ($P > 0.05$). For W-aged (vacuum packaged loins), BT resulted in similar weight loss to the C treatment ($P > 0.05$). However, BT loins had higher weight loss ($P < 0.05$) than C loins when they were D-aged (Fig. 1). Blade tenderization disrupts and opens up muscle structure, which allows moisture to escape from the interior of meat to the exterior more easily when the meat is unpackaged. D-aged steaks had much higher ($P < 0.01$) trim and combined loss as expected (Fig. 2). Similarly,

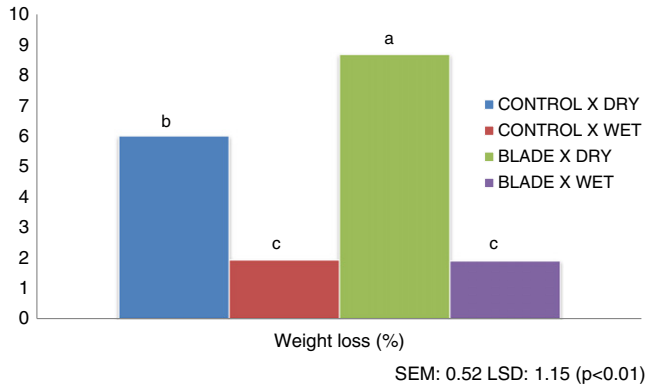

Fig. 1. Least square means for treatment × aging method interaction on weight loss (%) of *Longissimus lumborum* cull cow steaks.

Warren and Kastner (1992) reported higher weight loss with dry aging than that with W aging.

3.2. pH, moisture content, fat

Dry aging increased pH (5.47 vs 5.45, $P < 0.05$) compared to W-aging. For both C and BT steaks, pH increased with aging ($P < 0.05$). Nitrogenous compounds caused by proteolysis might be responsible for increased pH with aging as suggested by Aksu, Kaya, and Ockerman (2005).

An aging method × aging time interaction ($P < 0.001$) for moisture content existed. Steaks D-aged for 23 days had lower ($P < 0.01$) moisture content than those received the other treatment combinations (Fig. 3).

3.3. Shear force and cook loss

Blade tenderized and C steaks had WBSF values of 33.13 N and 41.46 N (SEM = 4.55 N), respectively. Albeit this difference in WBSF was not significant ($P = 0.09$), it likely still has practical importance. As animals mature, collagen becomes more cross-linked and heat resistant and more variation in tenderness is expected. Therefore, we might not have been able to detect shear force differences between treatments due to larger within animal variation, which inflated mean square of error, or our relatively few samples. Aging decreased WBSF ($P < 0.05$) as expected. Steaks aged for 2 days had WBSF of 39.75 N while those aged for 23 days had WBSF of 34.84 N (SEM = 2.06 N). Similarly, Wheeler, Shackelford, and Koohmaraie (1999) reported decreased WBSF with an increase in aging time. According to the "Standard Practice for Verifying Tenderness Marketing Claims Associated with Meat

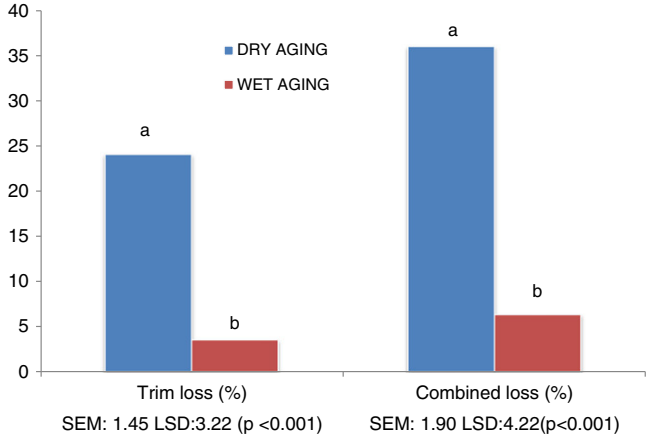

Fig. 2. Least square means for aging method on trim loss (%) and combined loss (%) of *Longissimus lumborum* cull cow steaks.

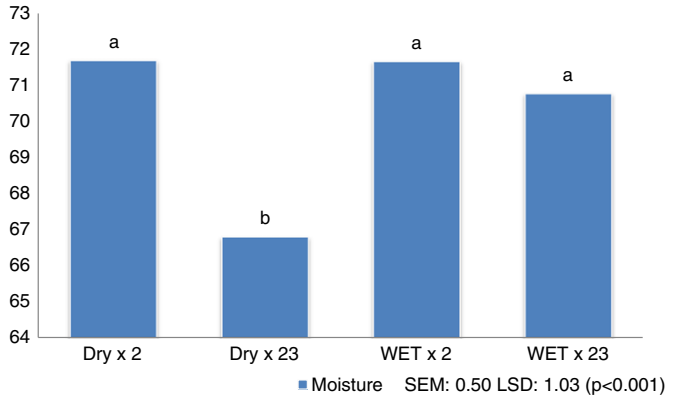

Fig. 3. Least square means for aging method × aging time interaction on moisture content (%) of *Longissimus lumborum* cull cow steaks.

Cuts Derived from Beef" (AMS, 2012), W-aged and/or BT steaks from cull dairy cows would have qualified for "USDA Certified Tender".

Blade tenderized steaks had higher ($P < 0.05$) cook loss (26.74% vs. 22.78%, SEM = 1.15%) than C steaks. Similarly, Obuz and Kropf (2002) reported higher cook losses with BT. In the study by King et al. (2009), BT steaks had higher cook loss than non-blade tenderized steaks. Moreover, aging method × aging time interaction was significant for cook loss ($P < 0.01$) in our study. D-aged steaks had less ($P < 0.01$) cook loss than W-aged steaks (Fig. 4) because less moisture was available for evaporation (Juárez et al., 2011). Similarly, Dikeman et al. (2013) reported lower cooking loss for D-aged steaks as compared to W-aged steaks.

3.4. Instrumental and visual color

Aging increased ($P < 0.01$) L^* values and decreased a^* and b^* values of uncooked steaks (Table 1). Treatment × day interaction ($P < 0.01$) was significant for a^* values with BT steaks aged for 23 d having lower a^* values than steaks aged for 2 d, which could possibly be explained by higher pigment oxidation with increased aging time. Aging method × day interaction was significant ($P < 0.01$) for a^* values with D-aged steaks for 23 d having the lowest a^* values (less red). The trend in b^* values was similar to that in a^* values.

Aging method × aging time interaction was significant ($P < 0.05$) for visual color of cooked steaks. Steaks D-aged for 23 d had higher degree of doneness scores than those aged for 2 d, or W-aged for 23 d (Fig. 5). Lower moisture content associated with D aging and increased aging time likely were responsible for higher visual degree of doneness observed as also suggested by Bertram, Engelsen, Busk, Karlsson, and Andersen (2004). Aging decreased ($P < 0.05$) redness evaluated by the visual panel, particularly for D-aging.

Table 1
Least square means of treatment, aging method, and aging day on instrumental color values of *Longissimus lumborum* cull cow steaks* ($n = 6$).

Source of variance	Cull cow steaks (raw)			Cull cow steaks (cooked)		
	L^*	a^*	b^*	L^*	a^*	b^*
Day						
2	32.7	16.2	11.3	54	13.4	17.7
23	39.7	13.8	9.4	55.3	10.9	14.3
P-value	<0.001	<0.001	<0.001	0.09	<0.001	<0.001
SEM	0.36	0.39	0.27	0.73	0.61	0.34
Treatment × day						
Control × 2	32.2	15^{b}	10.6^{b}	53.8	14.1	17.7
Control × 23	40	14.2^{b}	9.5^{c}	54.8	11.3	14.3
Blade × 2	33.2	17.3^{a}	12^{a}	54.1	12.6	17.7
Blade × 23	39.5	13.3^{b}	9.3^{c}	55.7	10.5	14.1
P-value	0.06	<.001	0.004	0.74	0.57	0.80
SEM	0.68	0.75	0.57	1.16	1.06	0.54
Aging method × day						
Dry × 2	32.7	16.2^{a}	11.3^{a}	53.5	13.9^{a}	17.9
Dry × 23	39.5	12.4^{b}	8.3^{c}	56.2	9.6^{b}	13.9
WET × 2	32.7	16.2^{a}	11.3^{a}	54.4	12.8^{a}	17.5
WET × 23	40	15.1^{a}	10.5^{b}	54.3	12.2^{a}	14.6
P-value	0.57	0.0015	<.001	0.06	0.005	0.13
SEM	0.52	0.55	0.37	1.03	0.87	0.48

*Within a column, LS means having a different superscript differ ($P < 0.05$).

L^* values (cooked) were not affected ($P > 0.05$) by treatment, aging method, aging or their two way and three way interactions (Table 1). However, aging method × aging interaction was significant ($P < 0.01$) for a^* values with steaks D-aged having the least redness. The b^* values increased ($P < 0.01$) with aging time. In summary, W-aging increased ($P < 0.01$) redness of uncooked steaks, whereas it decreased redness in cooked steaks. When steaks were BT and D-aged, they were less red than other treatment combinations. The 23 d aged cooked steaks were less red than 2 d aged cooked steaks. Blade tenderization had no effect ($P > 0.10$) on visual color of fresh steaks.

Blade tenderization had no effect ($P > 0.10$) on visual color of fresh steaks.

3.5. Sensory analysis

Aging and treatment × aging method interaction was significant ($P < 0.05$) for myofibrillar tenderness, overall tenderness, and off-flavor intensity. Myofibrillar and overall tenderness increased and off-flavor decreased for BT × W-aging compared to BT × D-aging because of aging method ($P < 0.05$) (Table 2), which agrees with the result of several studies (Laster et al., 2008; Sitz et al., 2006).

Irrespective of aging method used, BT improved myofibrillar tenderness ($P < 0.05$). Juiciness decreased with aging, which can be attributed

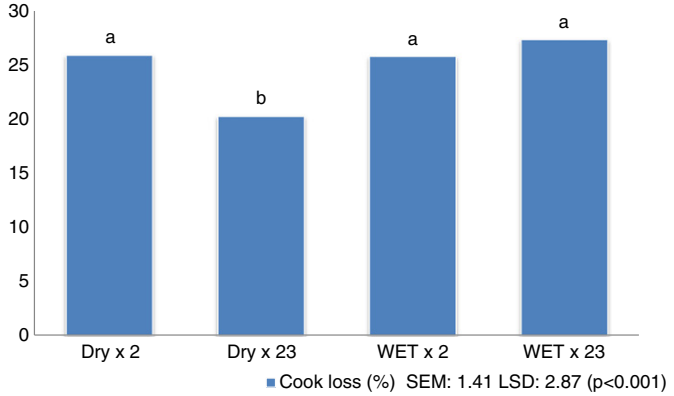

Fig. 4. Least square means for aging method × aging time interaction on cook loss (%) of *Longissimus lumborum* cull cow steaks.

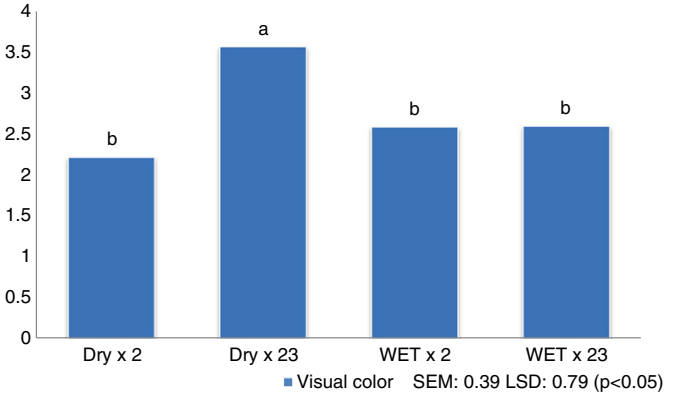

Fig. 5. Least square means for aging method × aging time interaction on visual cooked color of *Longissimus lumborum* cull cow steaks.

Table 2
Least square means of treatment, aging method, and aging day on sensory traits of *Longissimus lumborum* cull cow steaks* ($n = 6$).

Source of variance	Myofibrillar** tenderness	Juiciness**	Connective tissue amount**	Overall tenderness**	Beef Flavor intensity**	Off flavor intensity**
Aging method						
DRY	5.1	5.2	5.5	4.9	5.3	6.5
WET	5.4	5.3	5.8	5.3	5.4	7.2
P-value	0.03	0.08	0.14	0.005	0.11	<0.0001
SEM	0.11	0.09	0.14	0.11	0.09	0.13
Day						
2	4.7	5.4	5.1	4.5	5.2	6.9
23	5.8	5.1	6.2	5.7	5.4	6.7
P-value	<0.001	0.001	<0.001	<0.001	0.07	0.13
SEM	0.11	0.09	0.14	0.11	0.09	0.13
Treatment × aging method						
Control × DRY	5^{b}	5.4	5.3	4.7	5.4^{a}	6.9^{a}
Control × WET	5^{b}	5.4	5.4	4.9	5.4^{a}	7.1^{a}
Blade × DRY	5.2^{b}	5	5.8	5.1	5.1^{b}	6^{b}
Blade × WET	5.7^{a}	5.2	6.2	5.7	5.4^{a}	7.3^{a}
P-value	0.03	0.32	0.22	0.07	0.03	<.001
SEM	0.27	0.22	0.61	0.40	0.16	0.30
Aging method × day						
Dry × 2	4.6	5.4	4.9	4.3	5.2	6.8^{b}
Dry × 23	5.6	4.9	6.2	5.5	5.3	6.2^{c}
WET × 2	4.8	5.4	5.2	4.7	5.3	7.1^{ab}
WET × 23	5.9	5.2	6.3	5.9	5.5	7.3^{a}
P-value	0.75	0.11	0.75	0.93	0.85	0.02
SEM	0.15	0.13	0.20	0.15	0.13	0.19

SEM: Standard error of mean.
*Within a column, LS means having a different superscript differ ($P < 0.05$).
**1 = extremely tough, dry, bland, tough, and abundant; 8 = extremely tender, juicy, intense, tender, and none.

to increased weight loss over aging time Panelists gave higher connective tissue amount scores (less detectable connective tissue) to 23 d aged steaks as compared to those aged for 2 d suggesting that aging might have had some tenderizing effect on connective tissue. Similarly, less connective tissue amount with aging was reported in another study agreeing with our results (George-Evins et al., 2004). Aging method and aging time affected ($P < 0.05$) overall tenderness. W-aged steaks were rated higher than D-aged steaks by the panelists in terms of overall tenderness. Though significant ($P < 0.05$), the difference was about 0.3 (sensory score), which would likely be difficult for consumers to detect. Thus, this difference might not have much practical meaning. The 23 d aged steaks had higher ($P < 0.001$) overall tenderness than 2 d aged counterparts (Table 2). Similarly, higher overall tenderness ratings were given for steaks aged 21 vs. 7 d (George-Evins et al. (2004) in another study. Treatment × aging method was significant ($P < 0.05$) for beef flavor intensity, with the combination of BT and D-aging having the least flavor intensity. No or minimum differences in beef flavor intensity for D-aged versus W-aged steaks were reported in several studies (Laster et al., 2008; Sitz et al., 2006; Smith et al., 2008). In our study, the combination of BT and D-aging and D-aging by itself increased off-flavor intensity (both $P < 0.05$).

BT coupled with W-aging improves flavor intensity and reduces off-flavor (both $P < 0.05$) with no effect on juiciness. Our sensory panel results and in our WBSF results suggest that aging ($P = 0.02$) or BT ($P = 0.09$) improves tenderness of cow *Longissimus lumborum* steaks, which otherwise would be used only for processed or ground beef and have much less economical value. Our results imply that *Longissimus lumborum* steaks from cull dairy cows will have acceptable palatability when BT, aged 23 d, and W-aged. Wet aging is the more economical system because of much greater meat yield compared to D-aging.

4. Conclusions

Postmortem aging was very effective in improving sensory tenderness of cull Holstein cow *Longissimus lumborum* steaks ($P = 0.02$,) whereas blade tenderization was only effective when meat was wet aged. Generally, wet aging resulted in better palatability attributes than dry aging. The findings might have implications for the meat industry because practices such as blade tenderization and post mortem aging are found to improve the eating quality of cow meat, which could lead to increased use of the *longissimus* muscle from cull dairy cows as steaks. Vacuum (wet) aging is more economical than D-aging because of much greater meat yields. Sensory and WBSF means were quite acceptable for the combination of blade tenderization, vacuum packaging, and aging 23 d.

References

Aksu, M. I., Kaya, M., & Ockerman, H. W. (2005). Effect of modified atmosphere packaging and temperature on the shelf life of sliced pastirma produced from frozen/thawed meat. *Journal of Muscle Foods, 16*, 192–206.

AMS (2012). *Standard practice for verifying tenderness marketing claims associated with meat cuts derived from beef.: Agriculture Marketing Service of the U.S Department of Agriculture.*

AMSA (1991). *Guidelines for meat color evaluation.* Chicago, IL: American Meat Science Association.

AMSA (1995). *Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of fresh meat.* Chicago, IL: American Meat Science Association and the National Livestock and Meat Board.

Baublits, R. T., Pohlman, F. W., Brown, A. H., & Johnson, Z. B. (2005). Effects of sodium chloride, phosphate type and concentration, and pump rate on beef biceps femoris quality and sensory characteristics. *Meat Science, 70*, 205–214.

Bertram, H. C., Engelsen, S. B., Busk, H., Karlsson, A. H., & Andersen, H. J. (2004). Water properties during cooking of pork studied by low-field NMR relaxation: Effects of curing and the RN -gene'. *Meat Science, 66*, 437–466.

Burke, R. M., & Monahan, F. J. (2003). The tenderization of shin beef using a citrus juice marinade. *Meat Science, 63*, 161–168.

Christensen, M., Torngren, M.A., Gunvig, A., Rozlosnik, N., Lametsch, R., & Karlsson, A. H. (2009). Injection of marinade with actinidin increases tenderness of porcine M. biceps femoris and affects myofibrils and connective tissue. *Journal of the Science of Food and Agriculture, 89*, 1607–1614.

Dikeman, M. E. (1987). Fat reduction in animals and the effects on palatability and consumer acceptance of meat products. *Proc. 40th Recip. Meat Conf., St. Paul, Minnesota* (pp. 93–103).

Dikeman, M. E., Obuz, E., Gök, V., Akkaya, L., & Stroda, S. (2013). Effects of dry, vacuum, and special bag aging; USDA quality grade; and end-point temperature on yields and eating quality of beef *Longissimus lumborum* steaks. *Meat Science, 94*, 228–233.

Dikeman, M. E., & Tuma, H. J. (1971). Bovine muscle tenderness as related to protein solubility. *Journal of Food Science, 36*, 190–193.

George-Evins, C. D. (1999). *The effects of quality grade, postmortem aging, blade tenderization, and endpoint cooking temperature on Warner–Bratzler shear force, cooking*

characteristics, and sensory panel evaluation of longissimus, gluteus medius, and semimembranosus muscles. M.S. Thesis. Manhattan: Kansas State Univ.

George-Evins, C. D., Unruh, J. A., Waylan, A. T., & Marsden, J. L. (2004). Influence of quality classification, aging period, blade tenderization, and endpoint cooking temperature on cooking characteristics and tenderness of beef gluteus medius steaks. *Journal of Animal Science*, *82*, 1863–1867.

Heller, C. E., Scanga, J. A., Sofos, J. N., Belk, K. E., Warren-Serna, W., Bellinger, G. R., Bacon, R. T., Rossman, M. L., & Smith, G. C. (2007). Decontamination of beef subprimal cuts intended for blade-tenderization or moisture-enhancement. *Journal of Food Protection*, *70*, 1174–1180.

Hopkins, D. L. (2004). Tenderising mechanisms: Mechanical. In W. Jensen, C. Devine, & M. Dikeman (Eds.), *Encyclopedia of meat sciences* (pp. 1355–1363). Oxford: Elsevier.

Juárez, M., Caine, W. R., Dugan, M. E. R., Hidiroglou, N., Larsen, I. L., Uttaro, B., & Aalhus, J. L. (2011). Effects of dry-ageing on pork quality characteristics in different genotypes. *Meat Science*, *88*, 117–121.

King, D. A., Wheeler, T. L., Shackelford, S. D., Pfeiffer, K. D., Nickelson, R., & Koohmaraie, M. (2009). Effect of blade tenderization, aging time, and aging temperature on tenderness of beef *Longissimus lumborum* and gluteus medius. *Journal of Animal Science*, *87*, 2952–2960.

Kolle, B. K., McKenna, D. R., & Savell, J. W. (2004). Methods to increase tenderness of individual muscles from beef rounds when cooked with dry or moist heat. *Meat Science*, *68*, 145–154.

Laster, M.A., Smith, R. D., Nicholson, K. L., Nicholson, J.D. W., Miller, R. K., Griffin, D. B., Harris, K. B., & Savell, J. W. (2008). Dry versus W aging of beef: Retail cutting yields and consumer sensory attribute evaluations of steaks from ribeyes, strip loins, and top sirloins from two quality grade groups. *Meat Science*, *80*(3), 795–804.

Obuz, E., & Kropf, D. H. (2002). Will blade tenderization decrease iridescence in cooked beef semitendinosus muscle. *Journal of Muscle Foods*, *13*, 77–79.

Parrish, F. C., Jr. (1977). Skeletal muscle tissue disruption. *Proc. 30th Recip. Meat Conf., Auburn, Alabama* (pp. 87–98).

Parrish, F. C., Jr., Boles, J. A., Rust, R. E., & Olson, D.G. (1991). Dry and wet aging effects on palatability attributes of beef loin and rib steaks from three quality grades. *Journal of Food Science*, *56*, 601–603.

Pietrasik, Z., & Shand, P. J. (2004). Effect of blade tenderization and tumbling time on the process characteristics and tenderness of injected cooked roast beef. *Meat Science*, *66*, 871–879.

Pietrasik, Z., & Shand, P. J. (2005). Effects of mechanical treatments and moisture enhancement on the processing characteristics and tenderness of beef semimembranosus roasts. *Meat Science*, *71*(3), 498–505.

Pietrasik, Z., & Shand, P. J. (2011). Effects of moisture enhancement, enzyme treatment, and blade tenderization on the processing characteristics and tenderness of beef semimembranosus steaks. *Meat Science*, *88*(1), 8–13.

SAS. SAS user's guide (2009). Carry, NC: SAS Institute, Inc.

Savell, J. W., Cross, H. R., Francis, J. J., Wise, J. W., Hale, D. S., Wilkes, D. L., & Smith, G. C. (1989). National Consumer Retail Beef Study: Interaction of trim level, price and grade on consumer acceptance of beef steaks and roasts. *Food Quality*, *12*, 251–274.

Shorthose, W. R., & Harris, P. V. (1990). Effect of animal age on the tenderness of selected beef muscles. *Journal of Food Science*, *55*, 1–8.

Sitz, B.M., Calkins, C. R., Feuz, D.M., Umberger, W. J., & Eskridge, K. M. (2006). Consumer sensory acceptance and value of wet-aged and dry-aged beef steaks. *Journal of Animal Science*, *84*(5), 1221–1226.

Smith, R. D., Nicholson, K. L., Nicholson, J.D. W., Harris, K. B., Miller, R. K., Griffin, D. B., & Savell, J. W. (2008). Dry versus wet aging of beef: Retail cutting yields and consumer palatability evaluations of steaks from US Choice and US Select short loins. *Meat Science*, *79*(4), 631–639.

Stelzleni, A.M., Patten, L. E., Johnson, D.D., Calkins, C. R., & Gwartney, B.L. (2007). Benchmarking carcass characteristics and muscles from commercially identified beef and dairy cull cow carcasses for Warner–Bratzler shear force and sensory attributes. *Journal of Animal Science*, *85*, 2631–2638.

Toohey, E. S., Kerr, M. J., van de Ven, R., & Hopkins, D. L. (2011). The effect of a kiwi fruit based solution on meat traits in beef m. semimembranous. *Meat Science*, *88*, 468–471.

Tuma, H. J., Henrickson, R. L., Odell, G. V., & Stephens, D. E. (1963). Variation in the physical and chemical characteristics of the longissimus dorsi muscle from animals differing in age. *Journal of Animal Science*, *22*, 354–357.

USDA (2011). Livestock Slaughter 2010 Summary. **April.** National Agricultural Statistics Service. Accessed April.11, 2012. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1097

Warren, K. E., & Kastner, C. L. (1992). A comparison of dry-aged and vacuum-aged beef strip loins. *Journal of Muscle Foods*, *3*(1), 151–157.

Wheeler, T. L., Shackelford, S. D., & Koohmaraie, M. (1999). Tenderness classification of beef: III. Effect of the interaction between end point temperature and tenderness on Warner–Bratzler shear force of beef longissimus. *Journal of Animal Science*, *77*(2), 400–407.

Xiong, Y. L., Mullins, O. E., Stika, J. F., Chen, J., Blanchard, S. P., & Moody, W. G. (2007). Tenderness and oxidative stability of post-mortem muscles from mature cows of various ages. *Meat Science*, *77*, 105–113.